US009197870B1

(12) **United States Patent**
Soyannwo et al.

(10) **Patent No.: US 9,197,870 B1**
(45) **Date of Patent: Nov. 24, 2015**

(54) **AUTOMATIC PROJECTION FOCUSING**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 270 days.

(21) Appl. No.: **13/612,173**

(22) Filed: **Sep. 12, 2012**

(51) **Int. Cl.**

G03B 21/14	(2006.01)
H04N 9/31	(2006.01)
G03B 3/00	(2006.01)
A63F 13/00	(2014.01)

(52) **U.S. Cl.**
CPC ***H04N 9/3194*** (2013.01); ***G03B 3/00*** (2013.01); ***G03B 21/14*** (2013.01); *A63F 13/00* (2013.01); *H04N 9/3185* (2013.01)

(58) **Field of Classification Search**
CPC A63F 13/00; A63F 13/06; H04N 9/3185; H04N 9/3194; H04N 9/3197
USPC 353/28, 30, 69, 70, 79, 121, 122; 382/103, 162, 165, 167, 275, 276; 345/158, 419
See application file for complete search history.

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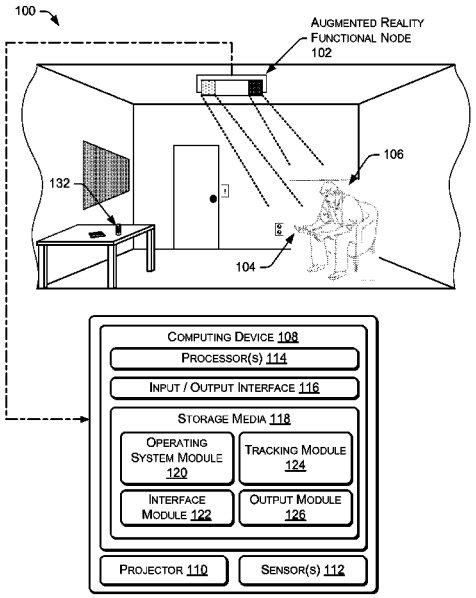
(57) **ABSTRACT**

Techniques are described for performing automatic focusing of a projected image on a mobile projection surface. Specific regions of the projected image are identified that are likely to be desired to stay in optimal focus, and attributes of those specific regions, such as sharpness and contrast, can be used to determine the need to refocus the image. Advanced knowledge of the image data being projected can be utilized to determine the specific regions of the projected image that require monitoring for optimal focusing.

23 Claims, 6 Drawing Sheets



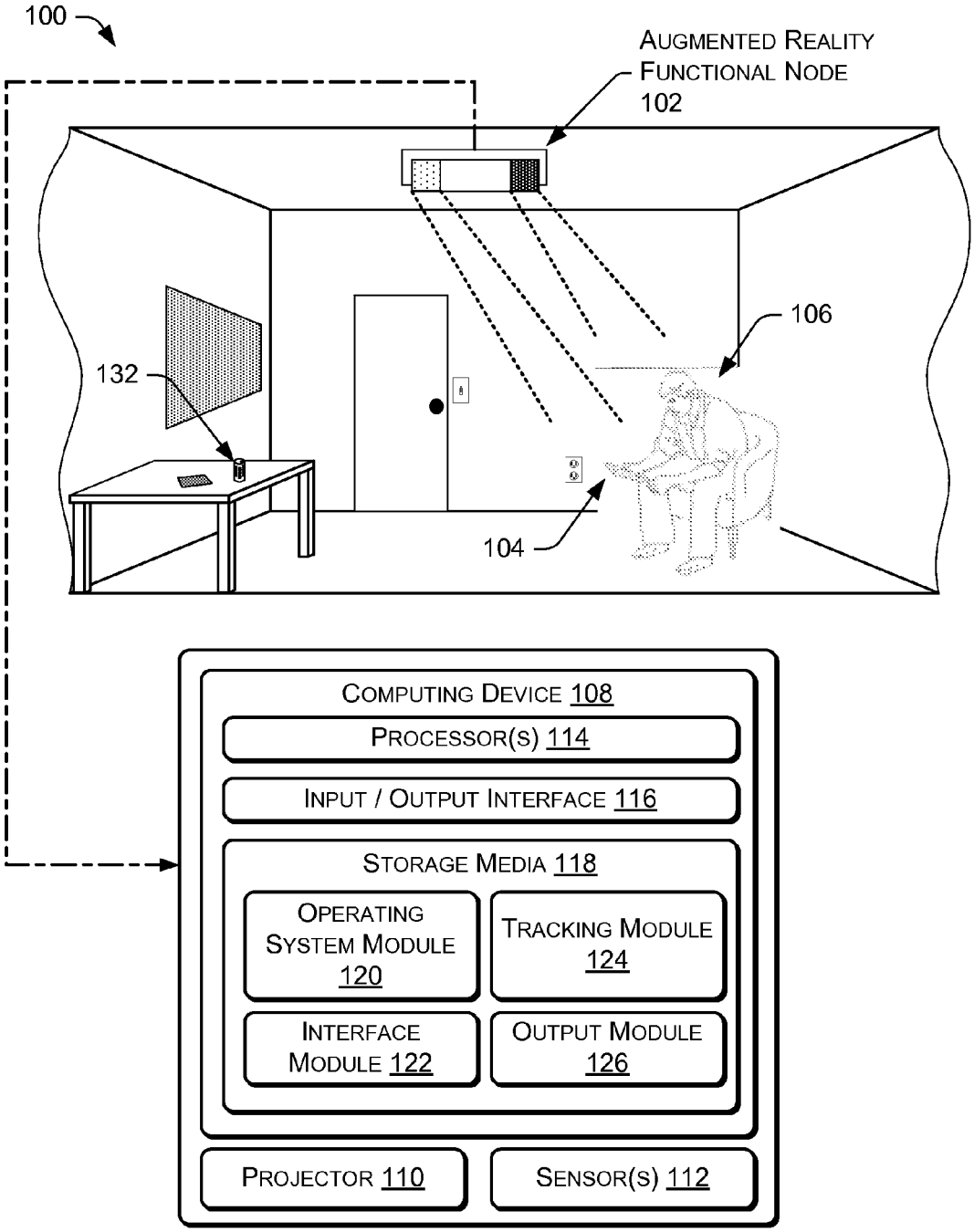

100
AUGMENTED REALITY FUNCTIONAL NODE 102
106
132
104
COMPUTING DEVICE 108
PROCESSOR(S) 114
INPUT / OUTPUT INTERFACE 116
STORAGE MEDIA 118
OPERATING SYSTEM MODULE 120
TRACKING MODULE 124
INTERFACE MODULE 122
OUTPUT MODULE 126
PROJECTOR 110
SENSOR(S) 112

FIG. 1

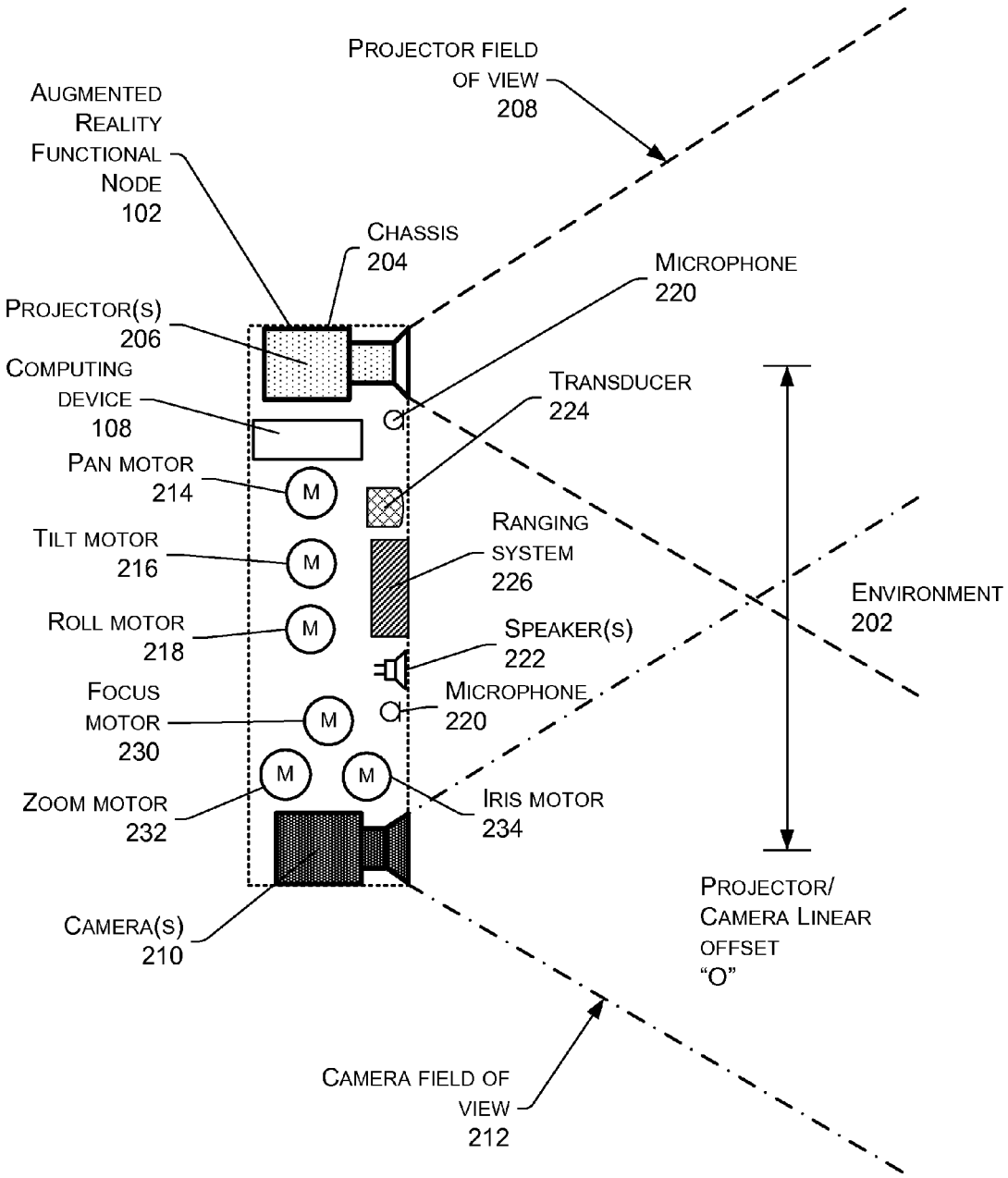

PROJECTOR FIELD OF VIEW 208
AUGMENTED REALITY FUNCTIONAL NODE 102
CHASSIS 204
MICROPHONE 220
PROJECTOR(S) 206
COMPUTING DEVICE 108
TRANSDUCER 224
PAN MOTOR 214
TILT MOTOR 216
RANGING SYSTEM 226
ENVIRONMENT 202
ROLL MOTOR 218
SPEAKER(S) 222
FOCUS MOTOR 230
MICROPHONE 220
ZOOM MOTOR 232
IRIS MOTOR 234
CAMERA(S) 210
PROJECTOR/ CAMERA LINEAR OFFSET "O"
CAMERA FIELD OF VIEW 212
M

FIG. 2

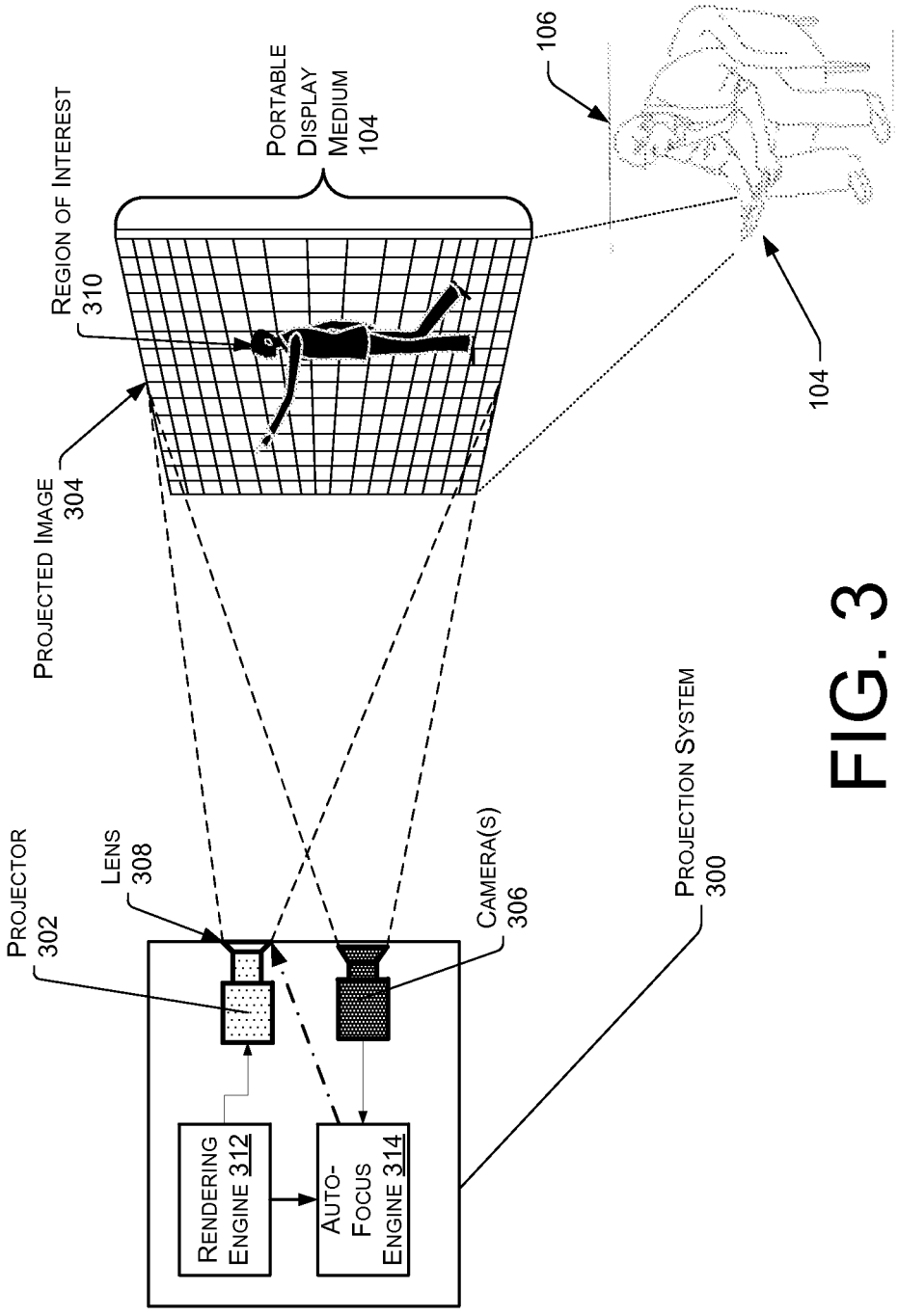

PROJECTION SYSTEM 300
PROJECTOR 302
LENS 308
CAMERA(S) 306
RENDERING ENGINE 312
AUTO-FOCUS ENGINE 314
PROJECTED IMAGE 304
REGION OF INTEREST 310
PORTABLE DISPLAY MEDIUM 104
106
104

FIG. 3

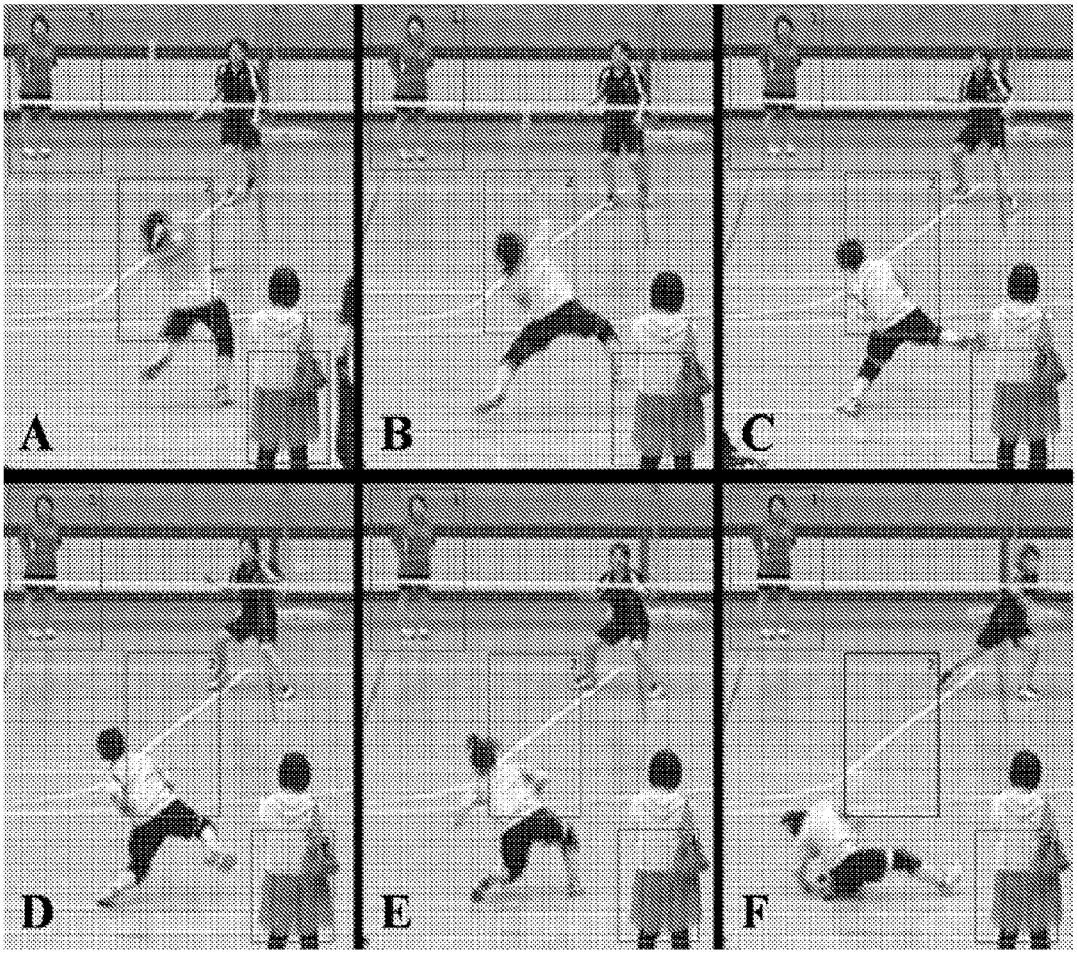


FIG. 4

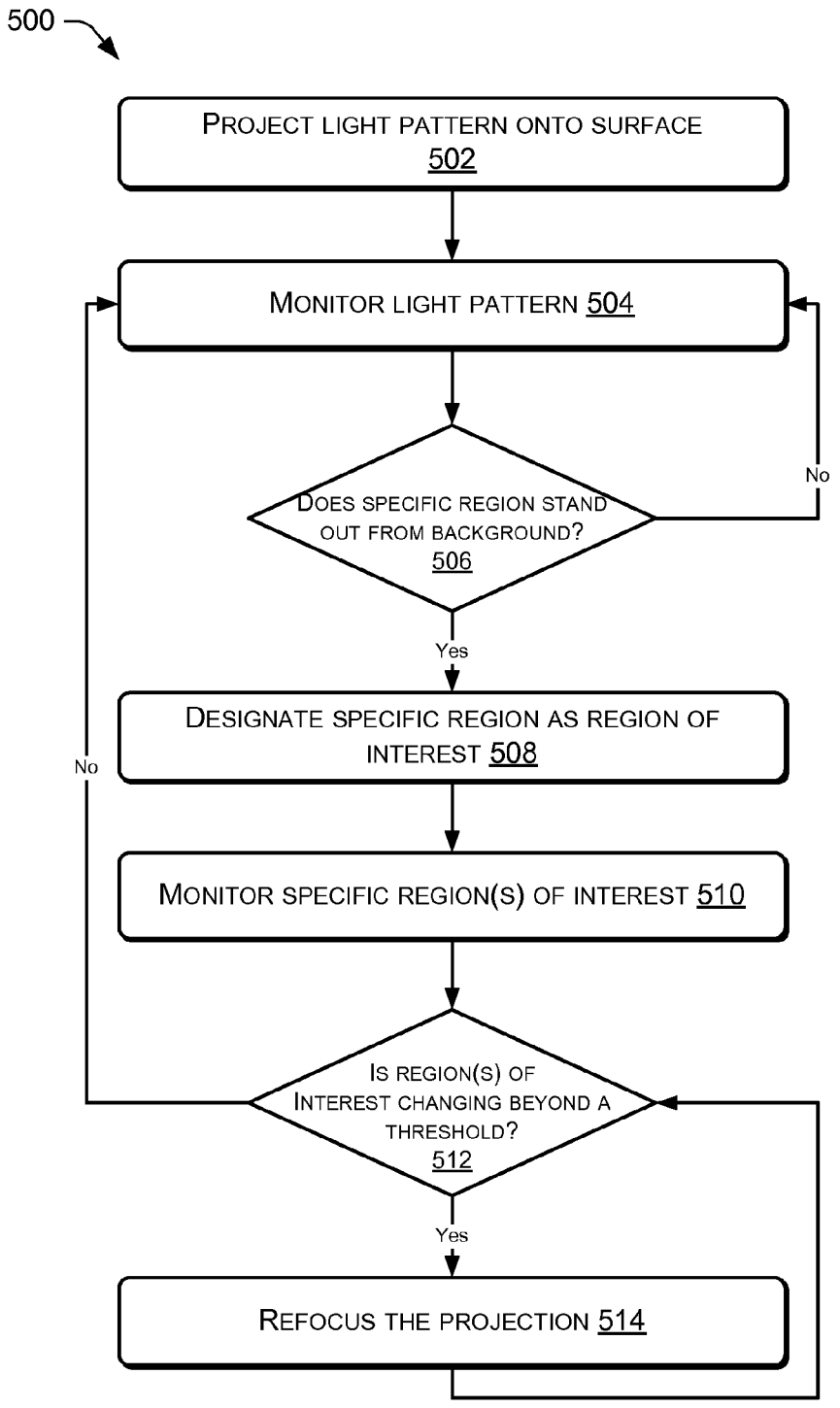

500
PROJECT LIGHT PATTERN ONTO SURFACE 502
MONITOR LIGHT PATTERN 504
DOES SPECIFIC REGION STAND OUT FROM BACKGROUND? 506
No
Yes
DESIGNATE SPECIFIC REGION AS REGION OF INTEREST 508
No
MONITOR SPECIFIC REGION(S) OF INTEREST 510
IS REGION(S) OF INTEREST CHANGING BEYOND A THRESHOLD? 512
Yes
REFOCUS THE PROJECTION 514

FIG. 5

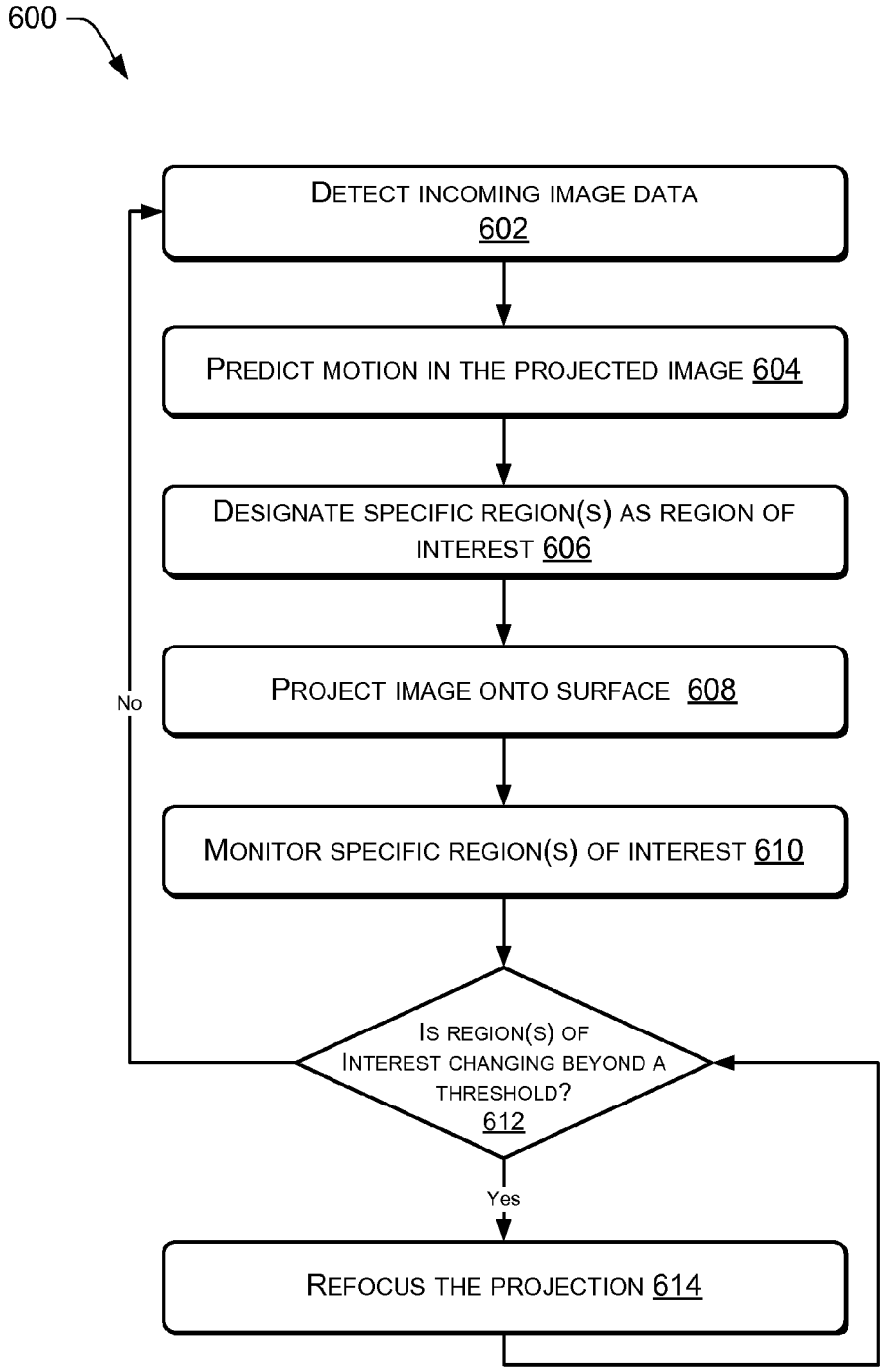

600
DETECT INCOMING IMAGE DATA 602
PREDICT MOTION IN THE PROJECTED IMAGE 604
DESIGNATE SPECIFIC REGION(S) AS REGION OF INTEREST 606
PROJECT IMAGE ONTO SURFACE 608
MONITOR SPECIFIC REGION(S) OF INTEREST 610
IS REGION(S) OF INTEREST CHANGING BEYOND A THRESHOLD? 612
No
Yes
REFOCUS THE PROJECTION 614

FIG. 6

AUTOMATIC PROJECTION FOCUSING

BACKGROUND

Existing projector systems typically project a dynamic and/or static image onto a surface and focus the image based autofocus algorithms that monitor one specific point or region of the image, e.g. a dead center of the projected image. This type of autofocus works sufficiently because the projection source is not expected to continuously change relative to the projection surface. However, in the case of a highly mobile projection surface or source, performing an autofocus without adversely impacting user experience becomes more difficult.

With the projector or surface reflecting the projected image in motion, the projected image may become distorted in any of three dimensions, and also may be projected on a surface at various angles. Moreover, the projected image typically has regions of interest to the viewer that might not be within the region of the image that the static autofocus is monitoring. Consequently, the use of an autofocus on a static region within the projected image may not adequately compensate for the motion of either the projector or surface, and does not necessarily keep the region of most likely interest to the viewer of the image in focus.

BRIEF DESCRIPTION OF THE DRAWINGS

The detailed description is described with reference to the accompanying figures. In the figures, the left-most digit(s) of a reference number identifies the figure in which the reference number first appears. The use of the same reference numbers in different figures indicates similar or identical components or features.

FIG. **1** shows an illustrative augmented reality functional node (ARFN) configured to perform the techniques described herein for projecting images into an augmented reality environment.

FIG. **2** shows additional details of an example ARFN that may be configured to provide a projected image.

FIG. **3** is an illustrative diagram of one embodiment of a projection system that autofocuses the projected image based on the monitoring of a specific region of interest.

FIG. **4** is a series of projected images in which specific regions of the image that are likely not to be in motion are identified and specifically monitored.

FIG. **5** is an illustrative flow diagram of one embodiment of the projection autofocus process that determines one or more regions of interest based upon the motion detected within the projected image.

FIG. **6** is an illustrative flow diagram of one embodiment of the projection autofocus process that determines one or more regions of interest based upon motion prediction within the image data that is to be projected.

DETAILED DESCRIPTION

This disclosure describes systems and techniques for performing the automatic focusing of a series of projected images where either the projector, the surface reflecting the projected image, or both, are potentially mobile. Specific regions of the projected images are identified that are not in motion relative to other portions of the images, and attributes of those specific regions, such as sharpness and contrast, can be used to determine the need to refocus the image.

In one embodiment, the system includes one or more processors, and one or more sensors communicatively coupled to the one or more processors, with the sensors including at least a camera. The system also includes a projector, and causes the projector to project the series of images in the form of a light pattern into an environment such that the light pattern is detectable by the camera, and then the system determines at least one specific region in the projected light pattern that is to be monitored for automatically focusing the light pattern. The system then monitors the at least one specific region in the projected light pattern for a predetermined threshold of a change in an image attribute, and refocuses the light pattern based upon the predetermined threshold being met.

In one embodiment, the system determines the region(s) of interest in the projected light pattern based upon review of the image data that comprises the projected light pattern, and can do so before the light pattern is projected or concurrently therewith. For instance, a camera can identity a portion of the projected light pattern that has not changed greatly over a number of frames and can use this portion to determine whether the projector should be focused. In another example, this determination of can be based upon motion prediction within the image data that comprises the projected light pattern. That is, the system may analyze the image date that is to be projected to determine which portion(s) of the projected light pattern can be used to determined whether the projected should be refocused due to a changed location of a display medium. By selecting areas of the light pattern comprising the series of projected images that are generally not in motion over a number of image frames, the camera can more easily identify any changes in focus in those areas.

Example Environments

FIG. **1** shows an illustrative augmented reality environment **100** that includes an augmented reality functional node (ARFN) **102** configured to perform the techniques described herein. When active, the ARFN node **102** may project content onto any surface within the environment **100**, such as a portable display medium **104**, thereby generating an augmented reality environment that may incorporate real-world objects within the environment **100**. The projected content may include electronic books, videos, images, interactive menus, or any other sort of visual and/or audible content. The ARFN node **102** scans the environment **100** to determine the presence of any objects, such a user **106** within the environment **100**, and can project content **104**, such as an image, on any surface.

As illustrated, the ARFN node **102** comprises a computing device **108**, a projector **110**, and one or more sensor(s) **112**. Some or the all of the computing device **108** may reside within a housing of the ARFN node **102** or may reside at another location that is operatively connected to the ARFN node **102**. The computing device **108** comprises one or more processor(s) **114**, an input/output interface **116**, and storage media **118**. The processor(s) **114** may be configured to execute instructions that may be stored in the storage media **118** or in other storage media accessible to the processor(s) **114**.

As illustrated, the user **106** holds a portable display medium **104**, onto which the projector **110** may project content for consumption by the user **106**. The sensor(s) **112** of the ARFN node **102** may capture images for detecting a location and orientation or the medium **104** for the purpose of instructing the projector where to project the content within the environment, as well as to focus the projection when the images projected onto the portable display medium become out of focus due to the shifting of the display medium in the user's hands.

The input/output interface **116**, meanwhile, may be configured to couple the computing device **108** to other components of the ARFN node **102**, such as the projector **110**, the sensor(s) **112**, other ARFN nodes **102** (such as in other environments or in the environment **100**), other computing devices, sirens, network communication devices (such as modems, routers, and wireless transmitters), a conventional security system, and so forth. The coupling between the computing device **108** and other devices may be via wire, fiber optic cable, wireless connection, or the like. The sensors may include, in various embodiments, one or more image sensors such as one or more cameras (motion and/or still cameras), audio sensors such as microphones, ultrasound transducers, heat sensors, motion detectors (including infrared imaging devices), depth sensing cameras, weight sensors, touch sensors, tactile output devices, olfactory sensors, temperature sensors, humidity sensors, and pressure sensors. Other sensor types and sensed attributes may be utilized without departing from the scope of the present disclosure.

The storage media **118**, meanwhile, may include computer-readable storage media ("CRSM"). The CRSM may be any available physical media accessible by a computing device to implement the instructions stored thereon. CRSM may include, but is not limited to, random access memory ("RAM"), read-only memory ("ROM"), electrically erasable programmable read-only memory ("EEPROM"), flash memory, or other memory technology, compact disk read-only memory ("CD-ROM"), digital versatile disks ("DVD") or other optical disk storage, magnetic cassettes, magnetic tape, magnetic disk storage or other magnetic storage devices, or any other medium which can be used to store the desired information and which can be accessed by a computing device **108**. The storage media **118** may reside within a housing of the ARFN, on one or more storage devices accessible on a local network, on cloud storage accessible via a wide area network, or in any other accessible location.

The storage media **118** may store several modules, such as instructions, datastores, and so forth that are configured to execute on the processor(s) **114**. For instance, the storage media **118** may store an operating system module **120**, an interface module **122**, a tracking module **124**, and an output module **126**.

The operating system module **120** may be configured to manage hardware and services within and coupled to the computing device **108** for the benefit of other modules. The interface module **122**, meanwhile, may be configured to receive and interpret commands received from users within the environment **100**. For instance, the interface module **122** may analyze and parse images captured by one or more cameras of the sensor(s) **112** to identify users within the environment **100** and to identify gestures made by users within the environment **100**, such as gesture commands to project display content. In other instances, the interface module **122** identifies commands audibly issued by users within the environment and captured by one or more microphones of the sensor(s) **112**. In still other instances, the interface module **122** allows users to interface and interact with the ARFN node **102** in any way, such as via physical controls, and the like.

The tracking module **124**, meanwhile, may be configured to track the portable display medium **104** through the environment **100**. For example, in instances where the user **106** carries the portable display medium **104** through the environment for receiving projected content, the tracking module **124** may track the location (e.g., in three space) and orientation of the display medium within the environment. The output module **126**, meanwhile, may be configured to receive this information from the tracking module **124**, determine where to project content based on this information, and periodically or continuously determine how to focus the projector **110** based on the location and orientation of the display medium. For instance, and as described in detail below, the output module **126** may determine how to focus a projected image on a display medium as the user **106** moves the display medium through the environment **100**.

The tracking module **124** may track the location and orientation of the portable display medium **104** using any type of depth-sensing technique. For instance, the projector may project a structured light pattern in the environment, and the camera may capture distortion in the structured light due to objects in the environment, such as the portable display medium. The system may then analyze this distortion to determine objects within the environment, as well as the locations and orientations of these objects. Of course, while one example is provided, it is to be appreciated that the tracking module **124** may track the portable display medium using any type of depth-sensing technique, such as time-of-flight or the like.

Example ARFN

FIG. **2** shows additional details of an exemplary ARFN node **102** that may be configured as described above with reference to FIG. **1**. The ARFN node **102** is configured to scan at least a portion of an environment **202** and the objects therein to detect and identify, such as the location and orientation of a portable display medium as a user moves the medium through the environment. The ARFN node **102** may also be configured to provide augmented reality output, such as images, sounds, and so forth.

A chassis **204** holds the components of the ARFN node **102**. One or more projector(s) **206** may be disposed within the chassis **204** and may be configured to generate and project light and/or images into the environment **202**. These images may be visible light images perceptible to an object, visible light images imperceptible to the object, images with non-visible light, or a combination thereof. This projector(s) **306** may be implemented with any number of technologies capable of generating an image and projecting that image onto a surface within the environment. Suitable technologies include a digital micromirror device (DMD), liquid crystal on silicon display (LCOS), liquid crystal display, 3LCD, and so forth. The projector(s) **206** has a projector field of view **308** which describes a particular solid angle. The projector field of view **208** may vary according to changes in the configuration of the projector. For example, the projector field of view **208** may narrow upon application of an optical zoom to the projector.

In some implementations, the ARFN node **102** may instruct devices that are separate from, but at least partially controllable by, the ARFN node **102** to visually or audibly output content. For instance, the ARFN node **102** may instruct a television or other display device within the environment to output a particular piece of visual content. Or, the ARFN node **102** may instruct stereo speakers within the environment to output certain audible content. In these instances, the projector(s) **206** may project non-visible structured light (or other types of light for sensing objects and objects and/or for sensing movement within the environment), while utilizing other output devices within the environment to output requested content, including content associated with one or more security actions such as but not limited to augmented reality security measures as described elsewhere within this Detailed Description. Of course, in other instances the projector(s) **206**

may be used instead of or in addition to the existing output devices within the environment.

One or more camera(s) **210** may also be disposed within the chassis **204**. The camera(s) **210** is configured to image the environment **202** in visible light wavelengths, non-visible light wavelengths, or both. The camera(s) **210** has a camera field of view **212** that describes a particular solid angle. The camera field of view **212** may vary according to changes in the configuration of the camera(s) **210**. For example, an optical zoom of the camera may narrow the camera field of view **212**.

In some implementations, a plurality of camera(s) **210** may be used. For instance, one embodiment of the ARFN node **102** may include a three-dimensional (3D), infrared (IR) camera and a red-green-blue (RGB) camera. The 3D, IR camera may be configured to capture information for detecting depths of objects within the environment **202**, while the RGB camera may be configured to detect edges of objects by identifying changes in color within the environment **202**. In some instances, a single camera may be configured to perform these functions.

The chassis **204** may be mounted with a fixed orientation, or may be coupled via an actuator to a fixture such that the chassis **204** may move. Actuators may include piezoelectric actuators, motors, linear actuators, and other devices configured to displace or move the chassis **204** or components therein such as the projector(s) **206** and/or the camera(s) **210**. For example, in one implementation the actuator may comprise a pan motor **214**, a tilt motor **216**, and so forth. The pan motor **214** is configured to rotate the chassis **204** in a yawing motion. The tilt motor **216**, meanwhile, is configured to change the pitch of the chassis **204**. In some instances, the ARFN additionally or alternatively includes a roll motor **218**, which allows the chassis **204** to move in a rolling motion. By panning, tilting, and/or rolling the chassis **204**, different views of the environment **202** may be acquired. Thus, the ARFN node **102** is mobile and the projected image from projector **206** will be effected by motion of the node **102**.

One or more microphones **220** may be disposed within the chassis **204**, or elsewhere within the environment **202**. These microphones **220** may be used to acquire input from an object, for echolocation, location determination of a sound, or to otherwise aid in the characterization of and receipt of input from the environment **202**. For example, an object may make a particular noise, such as a cough, a throat clear, a tap on a wall, or snap of the fingers, which are pre-designated as attention command inputs or as object detection noises. Such audio inputs may be located within the environment using time-of-arrival differences among multiple microphones and used to summon an active zone within the augmented reality environment or identify a location of the object, and can be to discern acoustic information from a surface. One or more speaker(s) **222** may also be present to provide for audible output, such as music, text-to-speech or the like.

A transducer **224** may be present within the ARFN node **102**, or elsewhere within the environment, and may be configured to detect and/or generate inaudible signals, such as infrasound or ultrasound. These inaudible signals may be used to provide for signaling between accessory devices and the ARFN node **102**.

The ARFN node **102** may also include a ranging system **226**. The ranging system **226** is configured to provide distance information from the ARFN node **102** to a scanned object, or other objects within the environment. The ranging system **226** may comprise radar, light detection and ranging (LIDAR), ultrasonic ranging, stereoscopic ranging, and so forth. In some implementations the transducer **224**, the microphones **220**, the speaker(s) **222**, or a combination thereof may be configured to use echolocation or echo-ranging to determine distance and spatial characteristics of an object.

In this illustration, the computing device **108** is shown within the chassis **204**. However, in other implementations all or a portion of the computing device **108** may be disposed in another location and coupled to the ARFN node **102**. This coupling may occur via wire, fiber optic cable, wirelessly, or a combination thereof. Furthermore, additional resources external to the ARFN node **102** may be accessed, such as resources in another ARFN node **102** accessible via a local area network, cloud resources accessible via a wide area network connection, or a combination thereof.

Also shown in this illustration is a projector/camera linear offset designated "O". This is a linear distance between the projector(s) **206** and the camera(s) **210**. Placement of the projector(s) **206** and the camera(s) **210** at distance "O" from one another may aid in the recovery of structured or other light data from the environment. The known projector/camera linear offset "O" may also be used to calculate distances, dimensioning, and otherwise aid in the characterization of objects within the environment **202**. In other implementations the relative angle and size of the projector field of view **208** and camera field of view **212** may vary. Also, the angle of the projector(s) **206** and the camera(s) **210** relative to the chassis **204** may vary.

Further illustrated in the embodiment of the node **102** in FIG. **2** are the focus controls motors, shown here as focus motion **230**, zoom motor **232** and iris motor **234**. Each of the motors can therefore either directly or indirectly control the focus of the image. The focus motor **230** can thus directly control the focus of the image camera **210** projects. The zoom motor **232** will zoom the image in an appropriate direction which can indirectly affect the focus of the projected image. The iris motor **234** adjusts the amount of light being projected and thereby also indirectly affects the focus of the image.

It should further be noted that the tilt motor **216**, pan motor **214** and roll motor **218** can likewise adjust the position of the node **102** to cause the projected image to change in relation to the surface upon which the image is projected, such as portable display medium **104** in FIG. **1**. Other motors can be used in the present node to adjust attributes of the camera **210** or node **102** to otherwise directly or indirectly adjust the focus of the projected image.

In other implementations, the components of the ARFN node **102** may be distributed in one or more locations within the environment **100**. As mentioned above, microphones **220** and speaker(s) **222** may be distributed throughout the environment. The projector(s) **206** and the camera(s) **210** may also be located in separate chassis **204**. The ARFN node **102** may also include discrete portable signaling devices used by objects to issue command attention inputs. For example, these may be acoustic clickers (audible or ultrasonic), electronic signaling devices such as infrared emitters, radio transmitters, and so forth.

The ARFN node **102** is shown in FIG. **2** with various sensors, but other sensors may be located either within or external to the chassis **204**. The sensors may include, in various embodiments, cameras (motion and/or still cameras), audio sensors such as microphones, ultrasound transducers, heat sensors, motion detectors (including infrared imaging devices), depth sensing cameras, weight sensors, touch sensors, tactile output devices, olfactory sensors, temperature sensors, humidity sensors, pressure sensors, and so forth.

FIG. **3** is an illustrative diagram of one embodiment of a projection system **300** that autofocuses a series of projected images based on a distance and/or orientation of a display

changing relative to a projector that projects the images. For instance, FIG. **3** illustrates a projector projecting content onto the portable display medium **104** being held by the user **106**. Because the user may move the medium **104** when consuming the content, the location and/or orientation of the medium relative to the projector may change, thus necessitating a change in focus of a lens of the projector to maintain image quality and viewing consistency for the user **106**. As described below, the techniques may continuously or periodically autofocus the project based on the monitoring of a specific region of interest **310**. This region of interest may be defined as a portion of series of images (e.g., a video) that has a relatively large degree of contrast around the edges and that changes very little over a series of frames. Given the contrast and static nature of such a region, the system may be able to accurately identify any changes in image quality due to an out-of-focus projection (due to changes in the location or orientation of the medium **104**).

In this instant illustration, the projector **302** projects a projected image **304** onto the display medium **104**. In some implementations a sequence of different projected images **304** may be used (e.g., a series of frames that collectively define a video). The distance orientation of the surface **104** relative to the projector **302** may change as the projector projects the image(s) **304** onto the surface **104** and, therefore, the focus of the projector **302** may need to dynamically change. As described above, this position and orientation of the surface **104** relative to the projector may be determined in any number of ways, such as via structured light, LIDAR, time-of-flight techniques or the like.

For illustrative purposes, a person is the region of interest **310** and is shown within the projected image **304**. That is, this region of interest **310** may represent a portion of the sequence of images that does not change greatly over a period of time (i.e., has little motion) and that has a relatively large contrast around its edges. In this embodiment, the source image data to be projected (e.g., the video to be projected) is provided to an auto-focus engine **314** and is used to reference image data to initially determine what will constitute the region of interest, such as the person as the region of interest **310**. In other words, the auto-focus engine **314** will predict, through motion analysis of the source image data, that the person in the projected image **304** is does not move in the images over a sequence of frames. The rendering engine **312** provides input from the image source (which can be raw buffer or motion vector information from video) going through projector **302** to the auto-focus engine **314**, which can then be synchronized with a frame sync pulse from the projector **302** to effect refocus of the region of interest **310**, if necessary. The camera **306** will monitor such attributes as sharpness, contract, brightness, etc., of the projected image **304** and interact with the projector **302** to start focusing the image through adjustable lens **308**.

As the projected image **304** is refocused, the camera **306** can also then capture the region of interest **310** attributes again and relays them to the auto focus engine **314** to determine if the refocusing is making the region of interest better for viewing. As described in more detailed below, a threshold of an attribute is predetermined, such as a specific level of sharpness or contrast, and the refocusing of the image is done based upon the threshold. If the region of interest **310** is distorted by the surface **104** having imperfections therein, or through the surface **104** being at a non-substantially-orthogonal relation to the projector **302**, a baseline can be set at the first few frames of content display such that auto-focus engine **314** can account for the baseline distortion in focusing the projected image **304**.

Further, the autofocusing can occur from either directly adjusting the focus of the image **304**, such as adjusting lens **308**, or can also occur through indirect methods, such as zooming the image (such as with zoom motor **232** in FIG. **2**), adjusting the amount of light being projected (such as with iris motion **234**), or by adjusting the positioning of the projector **302**. These adjustments can be made at the same time, or separately. Any methods of directly or indirectly affecting the focus of the projected image **304** known to one of skill in the art can be utilized in the projection system **300** to assist in optimally focusing the projected image **304**.

FIG. **4** represents a series of images that collectively form a portion of a video that may be projected onto a portable display medium. Using the techniques described above, regions of these images having a relatively high contrast may be identified for the potential use of monitoring these regions over time to determine whether the projector should be refocused.

FIG. **4** illustrates a series of projected images A-F in which specific regions 1-3 of the image that have high contrast therein and, therefore, may be monitored for purposes of autofocusing. In this video sequence, a predefined number of consecutive frames A-F are captured either via image data processing on the incoming video stream or through the camera sensing the live display (e.g., frame by frame), and the data is processed to determine a region of interest for monitoring and potential refocusing. The first image A is used as a background image and the potential areas of interest are identified, here area 1, 2, and 3. The most ideal regions are selected here based on the contrast score versus the initial background. In the frame A, each selected regions 1, 2 and 3 are compared for significant change in contrast/scenery and thus stand out from the background. Then significant motion changes are noted within the selected regions as the frame rate progresses, and the same steps are repeated for B, C, D and E to create, for instance, a 5 frame sample.

At the end of the sampling period, the algorithm is able to determine which regions remain mostly consistent, e.g. 1 and 3, and which is in motion, e.g. frame 2. The contrast score or sharpness algorithm is then run on the regions having the high contrast and yet do not include a great degree of motion. Here, region 2 can be may be discarded given its large degree of motion through the sequence, while region 1 & 3 are used to determine whether the projector should be refocused. In such an embodiment, the final focus score is used as input to determine if the image is in focus.

If focusing is needed based upon the algorithm used, the lens **308** in FIG. **3** will adjust the image, and the same steps are repeated until a convergence is realized and the threshold values of contrast and sharpness are reached. It should be further noted that the number of potential regions of interest is not limited and other algorithms can be used to determine when the image is out of focus.

Example Processes

FIG. **5** is an illustrative flow diagram of one embodiment of the projection autofocus process **500** that determines one or more regions of interest based upon the motion detected within the projected image. At step **502**, a light pattern representing a series of one or more images (such as projected image **304** in FIG. **3**) is projected onto a surface (such as the display medium **104**). At step **504**, the light pattern is monitored. For example, frames A-F can initially monitored as shown in FIG. **4**. Then a determination is made as to whether one or more specific regions of the image stand out from the

background and include an amount of motion that is less than a threshold, as shown at decision **506**.

If no specific regions of interest are identified at decision **506**, then the process iterates to again monitor the light pattern at step **504**. For example, if no regions of interest existed in the first 5 frames because there was not sufficient contrast or because each region having a sufficiently high contrast contained too much motion, then the process iterates to monitor the next 5 frames. If one or more regions of interest can be identified at decision **506**, then the specific region is identified as a specific region of interest for the next monitoring period, as shown at step **508**, and is then monitored throughout the next monitoring period as shown at step **510**, e.g. the next 5 frames.

A determination is then made as to whether the monitored region(s) of interest is changing beyond a predetermined threshold, as shown at decision **512**. The predetermined threshold can be a minimum level of sharpness, contrast, or any other attribute indicative of the focus of the image. If the region(s) of interest have not changed beyond the threshold in decision **512**, then the process iterates to again monitor the light pattern at decision **504**. Otherwise, if the region(s) of interest has changed at decision **512**, then the projection is refocused as shown at step **514** and the process iterates at decision **512** until the one or more regions of interest are in adequate focus again.

FIG. **6** is an illustrative flow diagram of one embodiment of the projection autofocus process **600** that determines the region of interest based upon motion prediction based upon the image data that is to be projected. This process can be performed by the projection system **300** in FIG. **3** with the rendering engine **312** and auto-focusing engine **314**. The incoming image data is detected as shown at step **602** and, as in the example in FIG. **3**, the rendering engine **312** will send the incoming image data to the autofocus engine **314**. Thereafter, motion within the image data is that is to be projected is determined, as shown at step **604**.

Once the motion is predicted within the image at step **604**, one or more region of interest are designated as shown at step **606**. As described above, these region(s) of interest comprise those regions having a sufficiently high level of contrast and yet include little motion over a number of frames. After identifying the regions of interest, the image data is projected on the surface (such as on the display medium **104** in FIG. **3**) as shown at step **608**. The region(s) of interest in the projected image are then monitored as shown at step **610**. Thus, with reference to the projection system **300** of FIG. **3**, the camera **306** will monitor the projected image **304** and regions of interest (such as regions 1-3 of images A-F in FIG. **4**), and such monitoring will typically occur for a set period of frames as has been described herein.

After the monitoring period is complete at step **610**, then a determination is made as to whether the monitored region(s) of interest is changing beyond a predetermined threshold, as shown at decision **612**. The predetermined threshold can be a minimum level of sharpness, contrast, or any other attribute indicative of the focus of the image. If the region(s) of interest have not changed beyond the threshold in decision **612**, then the process iterates to again detect the incoming image data at step **602** and start to generate the region(s) of interest for monitoring. Otherwise, if the region(s) of interest has changed at decision **612**, then the projection is refocused as shown at step **614** and the process iterates at decision **612** until the one or more regions of interest are in adequate focus again.

CONCLUSION

Although the subject matter has been described in language specific to structural features, it is to be understood that the subject matter defined in the appended claims is not necessarily limited to the specific features described. Rather, the specific features are disclosed as illustrative forms of implementing the claims.

What is claimed is:

1. A method comprising:

under control of one or more computing systems configured with specific executable instructions,

projecting one or more images on a surface within an environment;

capturing image information from the environment;

based at least in part on analyzing the captured image information, determining at least one region in the projected one or more images that is to be monitored;

based at least in part on analyzing the captured image information, monitoring the at least one region in the projected one or more images for a threshold of a change in an image attribute associated with the at least one region; and

adjusting projection of the one or more images based at least in part upon the threshold being met.

2. The method of claim **1**, further comprising determining the at least one region in the projected one or more images based at least in part upon review of image data in the environment that comprises the projected light pattern.

3. The method of claim **2**, further comprising:

predicting motion for an object in the one or more images based upon review of image data that is to be projected; and

determining the at least one region in the projected one or more images based upon the predicted motion within the image data.

4. The method of claim **1**, further comprising:

capturing motion in the one or more images that are displayed on the surface; and

determining the at least one region in the projected one or more images based at least in part upon determining that an amount of a motion within that the at least one region over a number image frames is less than another threshold.

5. The method of claim **1**, further comprising changing the threshold for the region being monitored upon the adjusting of the projection of the one or more images in that region.

6. The method of claim **1**, further comprising changing a frequency of monitoring of the region upon the adjusting of the projection of the one or more images in that region.

7. The method of claim **1**, further comprising:

determining if the projected one or more images is distorted by the surface on which the one or more images is projected;

establishing a baseline distortion of the projected one or more images for the surface on which the one or more images is projected; and

monitoring the at least one region in the projected one or more images for a threshold of a change in the image attribute associated with the at least one region accounting for the baseline distortion within the region.

8. The method of claim **1**, wherein adjusting projection of the one or more images is adjusting the focus for the one or more images.

9. One or more non-transitory computer readable media storing computer-executable instructions executable by one or more processors to cause the one or more processors to:

cause a projector to project a one or more images on a surface within an environment;

capture image information from the environment;

based at least in part on analyzing the captured image information, determine at least one region in the projected one or more images that is to be monitored;

based at least in part on analyzing the captured image information, monitor the at least one region in the projected one or more images for a threshold of a change in an image attribute associated with the at least one region; and

adjust projection of the one or more images based at least upon the threshold being met.

10. The one or more non-transitory computer readable media of claim **9**, wherein the computer-executable instructions are further executable to:

determine the at least one region in the projected one or more images based at least in part upon review of image data in the environment that comprises the projected light pattern.

11. The one or more non-transitory computer readable media of claim **10**, wherein the computer-executable instructions are further executable to:

predict motion for an object in the one or more images based upon review of image data that is to be projected; and

determine the at least one region in the projected one or more images based upon the predicted motion within the image data.

12. The one or more non-transitory computer readable media of claim **9**, wherein the computer-executable instructions are further executable to:

capture motion in the one or more images that are displayed on the surface; and

determine the at least one region in the projected one or more images based at least in part upon determining that an amount of a motion within that the at least one region over a number image frames is less than another threshold.

13. The one or more non-transitory computer readable media of claim **9**, wherein the computer-executable instructions are further executable to:

change the threshold for the region being monitored upon the adjusting of the projection of the one or more images in that region.

14. The one or more non-transitory computer readable media of claim **9**, wherein the computer-executable instructions are further executable to:

change a frequency of monitoring of the region upon the adjusting of the projection of the one or more images in that region.

15. The one or more non-transitory computer readable media of claim **9**, wherein the computer-executable instructions are further executable to:

determine if the projected one or more images is distorted by the surface on which the one or more images is projected;

establish a baseline distortion of the projected one or more images for the surface on which the one or more images is projected; and

monitor the at least one region in the projected one or more images for a threshold of a change in the image attribute associated with the at least one region accounting for the baseline distortion within the region.

16. The one or more non-transitory computer readable media of claim **9**, wherein adjusting projection of the one or more images is adjusting the focus of the one or more images.

17. A system comprising:

one or more processors;

a camera;

a projector; and

one or more non-transitory computer-readable storage media storing computer-executable instructions that are executable by the one or more processors to cause the one or more processors to:

cause the projector to project one or more images to be displayed on a surface of an environment;

capturing image information from the environment;

based at least in part on analyzing the captured image information, determine at least one region in the projected one or more images that is to be monitored;

based at least in part on analyzing the captured image information, monitor the at least one region in the projected one or more images for a threshold of a change in an image attribute associated with the at least one region; and

adjust projection of the one or more images based at least in part upon the threshold being met.

18. The system of claim **17**, wherein the instructions are further executable to:

determine the at least one region in the projected one or more images based at least in part upon review of image data in the environment that comprises the projected one or more images.

19. The system of claim **18**, wherein the instructions are further executable to:

predict motion for an object in the one or more images based upon review of image data that is to be projected; and

determine the at least one region in the projected one or more images based at least in part upon the predicted motion within the image data.

20. The system of claim **17**, wherein the instructions are further executable to:

capture motion in the one or more images that are displayed on the surface; and

determine the at least one region in the projected one or more images, based at least in part upon determining that an amount of a motion within that the at least one region over a number image frames is less than another threshold.

21. The system of claim **17**, wherein the adjusting projection of the one or more images is adjusting the focus of the one or more images and the instructions are further executable to:

change the threshold for the region being monitored upon the adjusting of the focus of the one or more images in that region.

22. The system of claim **17**, wherein the adjusting projection of the one or more images is adjusting the focus of the one or more images and the instructions are further executable to:

change a frequency of monitoring of the region upon the adjusting of the focus of the one or more images in that region.

23. The system of claim **17**, wherein the instructions are further executable to:

determine if the projected one or more images is distorted by the surface on which the one or more images is projected;

establish a baseline distortion of the projected one or more images for the surface on which the one or more images is projected; and

monitor the at least one region in the projected one or more images for a threshold of a change in the image attribute associated with the at least one region accounting for the baseline distortion within the region.

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